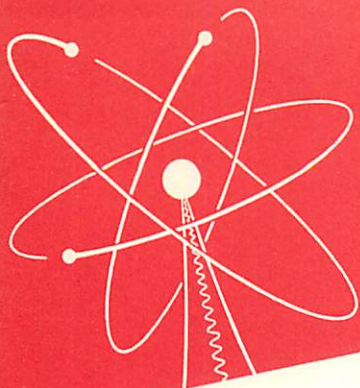




UHF TUNERS

Lesson T2C-17A



DeVRY Technical Institute

4141 W. Belmont Ave., Chicago 41, Illinois

Formerly DeFOREST'S TRAINING, INC.

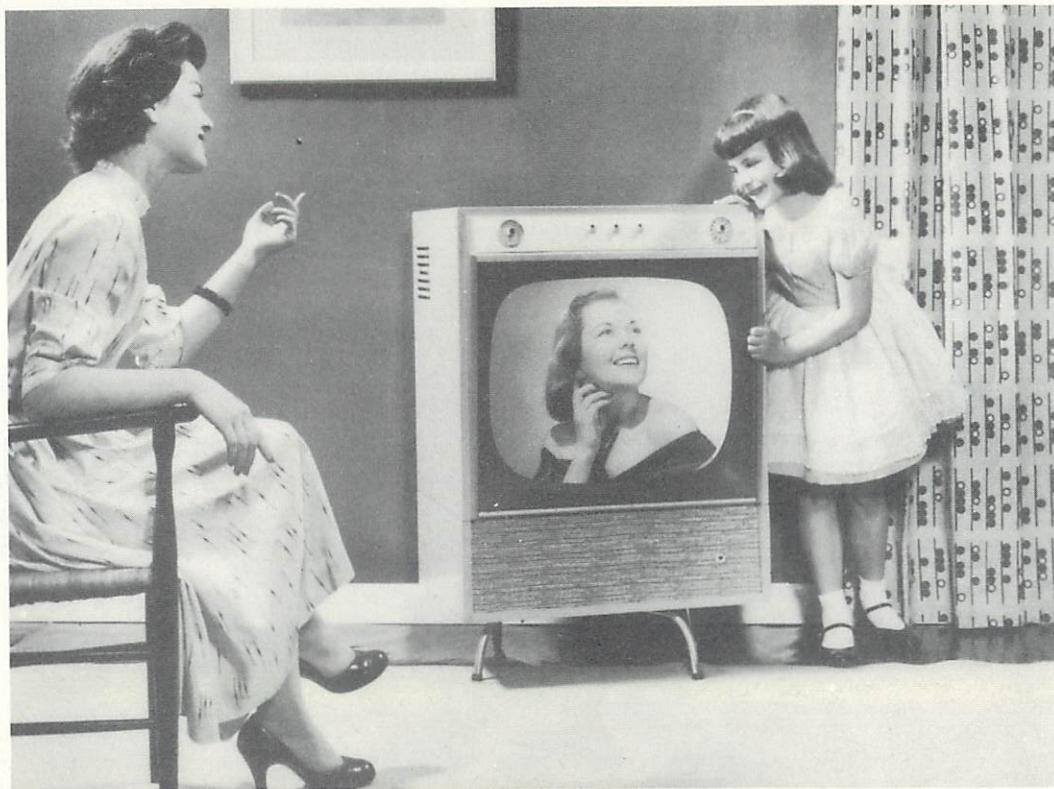
UHF TUNERS

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Mounted on a swivel base for convenient viewing in any part of the room, this receiver has its screen tilted downward to reduce glare and its control panel tilted upward for easy adjustment.

Courtesy Westinghouse Electric Corp.

UHF TUNERS

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Any kind of knowledge gives a certain amount of power.
A knowledge of details has served in many a crisis. A
knowledge of details has often caught an error before it
became a catastrophe.

—Aimee Buchanan

UHF TUNERS

RECEIVING EQUIPMENT

In the broad meaning of the word radio, electromagnetic waves carry intelligence through space from the transmitting apparatus to one or more points of reception. Depending upon the specific application, the transmitted intelligence has some particular form, such as the video and audio information required for television. In general, the receiving equipment consists of an antenna to intercept the radiated waves, a transmission line to carry the radio energy to the receiver input, a means of selecting and amplifying a carrier wave of a particular frequency, a demodulator to recover the modulating signals, and a device which converts these signals to visual, aural, or other useful form. Although all receivers include the means to perform these basic functions, the actual components vary considerably in physical construction, depending upon the frequency range in which the carrier waves exist.

Although the antenna, lead-in, tubes, and tuning components employed in A-M broadcast radio would work in VHF television receivers where the r-f carrier range is from 54 to 216 mc, those designed for television reception are more efficient at these frequencies. In the case of microwave

equipment, the components have physical dimensions as great or greater than the wavelengths of the carrier waves which have frequencies of over 1000 mc. For example, radar systems use large dish-shaped antennas many wavelengths in diameter, rectangular hollow tubes called wave guides in place of lead-ins and other connecting leads, and specially constructed tubes and tuning devices. Although television equipment would work at microwave frequencies, it would be less efficient than that designed for microwaves. On the other hand, microwave type equipment could be designed for television use, but would be extremely large and cumbersome because the television carrier wavelengths are much longer than the microwaves. Thus, each radio application operates best with components designed for its own frequency range.

For UHF television, the entire frequency range is from 470 mc to 890 mc. Although considerably higher than the VHF band, the UHF band does not reach the range of the microwaves. In the television receiver, besides the antenna and lead-in, the only section directly concerned with the carrier wave is the tuner. Thus, a television receiver designed for UHF reception contains tuner

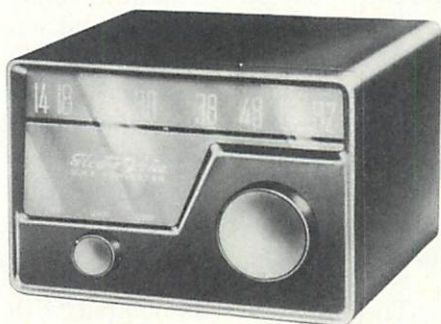
circuits which operate in the 470 to 890 megacycle band, and employs a UHF antenna system, but otherwise is exactly like the receivers used for VHF reception. The various television antenna types and transmission lines are taken up in other lessons of this series, while this lesson describes UHF tuners, the components of which are different from those found in either VHF television or microwave receivers.

UHF TUNER STAGES

Basically, the **uhf tuner** stages are much like those of the VHF r-f stages. The general arrangement of the UHF tuner is given in the block diagram of Figure 1. The unit has a channel selector containing the LC tuning circuits which pass the desired carrier waves and sidebands received from the antenna, and reject all others. This selector corresponds to the r-f amplifier stage in the VHF tuner. The selected signals are applied to the input of the mixer. Also applied to the mixer is an r-f voltage from the local source. The local r-f source may be either an oscillator as in the VHF tuner, or a tuned circuit which selects a desired harmonic of the r-f voltage generated by an oscillator.

The mixer circuit heterodynes the oscillator voltage with the picture and sound r-f carriers to pro-

duce a set of lower or intermediate frequency signals which carry the original modulation. Again, this action corresponds with that in the VHF tuner. However, in the case of the UHF tuner, the i-f output of the mixer may be in either the 40 mc range or the range of the VHF television r-f channels. When it is in the 40 mc range, it is applied directly from the tuner amplifier to the receiver i-f amplifier. In the other method, the UHF mixer produces a set of i-f carriers equal respectively to the picture and sound carriers of one of the VHF channels. These carriers are applied to the input of the receiver VHF tuner which, in turn, converts them to i-f signals in the 40 mc range. These i-f signals are applied to the i-f amplifier the same as with signals received from stations broadcasting in the VHF bands.



A UHF converter, tunable from channel 14 through channel 83, provides UHF reception with existing VHF receivers.

Courtesy Electro-Voice, Inc.

Another difference is that, usually, the UHF tuner employs a

diode type mixer rather than a triode or pentode. Instead of providing signal gain, the diode mixer causes loss of signal strength. To make up for this loss, the level of the mixer i-f output is increased by means of the amplifier shown in Figure 1, before it is applied to either the receiver i-f amplifier or the VHF converter, as the case may be.

Preselector

To provide high selectivity, any LC tuned circuit should have high Q . The Q factor is a comparison of the reactance and the resistance in a coil, capacitor, or tuned circuit. Within the tuned circuit, the series resistance should be low to provide the desired high Q . In a given LC circuit, the inductance and capacitance required depend upon the frequency to which the circuit must be resonant. The reactances of the inductor and capacitor are determined by the inductance and capacitance values and the frequency of the signal current. Thus, the r-f carrier frequencies in a given application determine the reactances in the tuning circuits.

The resistance associated with a tuned circuit consists of the inductor wire resistance, the resistance of connecting leads, connections, and switch contacts, and the resistance of other components connected in parallel with

the tuned circuit. At high frequencies, where the inductor is a coil of only a few turns, its direct-current resistance is low, but its alternating-current resistance is high due to the skin effect. The lead resistances, etc. can be decreased to some extent by careful construction methods.

However, the total resistance within the tuned circuit cannot be reduced in the same proportion as the reactances decrease when tuned circuits are designed to resonate at higher and higher frequencies. As a result, the circuit Q and therefore the selectivity become lower with increase of operating frequencies.

When the tuning circuit is part of an amplifier stage, as in VHF television tuners, the r-f amplifier tube presents a resistance component which shunts the LC circuit. Since it is in parallel with the tuned circuit, this input resistance should be large to permit high Q . The amplifier input resistance component is a result of conductance effects in the tube circuit. Thus, the greater these conductances, the lower the resistance shunting the LC circuit, and the lower the Q .

As explained in a preceding lesson on tuner circuits, one source of conductance is the fact that the envelope and other nonconducting parts of the tube are not perfect

insulators. That is, the glass envelope and insulating supports actually permit extremely small amounts of electron flow between the various leads and electrodes.

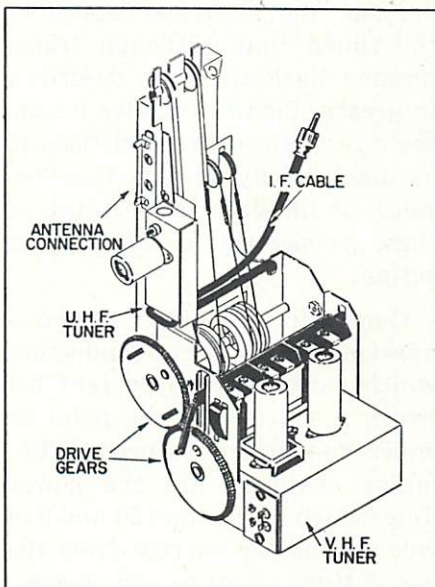
Also explained previously, transit time effects produce an in-phase component of grid displacement current, which is the same result that would be obtained if a resistor were connected from grid to cathode.

A third source of conductance in the tube circuit is the inductance of the cathode lead which also produces a component of grid displacement current in phase with the grid voltage.

Again, certain construction methods are employed which reduce these conductances to low values, and thus increase the input resistance of the r-f amplifier tube. With specially designed tubes and semi-lumped circuit components, grounded-grid r-f amplifiers have been made which operate successfully at frequencies up to 1000 mc. However, these amplifiers require complicated tuned circuit design to achieve the necessary selectivity.

As an alternative, the r-f amplifier and its Q-reducing conductances are omitted in most television receiver UHF tuners. One or more tuned LC circuits provide the required selectivity to pick out the desired carriers from

those presented by the antenna system to the receiver input. Called the **preselector**, these input tuning circuits are represented in Figure 1 by the block labeled "channel selector".



In this assembly, the UHF tuner is a single conversion, continuous tuning device mounted directly over the VHF tuner.

Courtesy Raytheon Television and Radio Corp.

One tuning method used employs the turret system explained for the VHF tuners. Here, individual strips contain the inductors and capacitors needed by the preselector and oscillator for each of the UHF stations in the area in which the receiver is to be operated. The strips are mounted on a drum type switch, and rotation of the tuning knob turns the drum to connect the desired set of LC

components into the tuner circuits.

Another common method consists of employing sections of transmission lines as tuned circuits. Tuning is accomplished by varying the electrical length of the **tuned line**. Although transmission lines are to be described in greater detail in a later lesson, their resonant characteristics are outlined briefly at this time because of the great importance of these properties in UHF tuner action.

Generally speaking, a transmission line is a set of conductors which carry electric current between a source and the point at which the current is needed. Familiar examples are the power lines which carry the 120 and 240 volt alternating current from the generating plant to our homes, and the telephone lines which carry the voice modulated currents to provide us with two-way, instantaneous communication. Much shorter transmission lines are those which connect antennas to radio and television receivers, and the line cords which connect electric appliances to the wall outlets.

Usually, the line consists of a pair of wires or conductors separated from each other by a non-conducting or dielectric material. Every conductor has a certain small amount of resistance per

unit length, and every insulating material has a small amount of conducting ability. The conductor resistance results in power loss as given by the product I^2R , where R is the total resistance of the wire. Also, the conductivity of the insulating material provides what we might consider a very high resistance "short circuit" between the wires of the line, and thus causes losses due to the minute current carried by this high resistance.

In addition, every conductor has a definite inductance per unit length, while the two conductors of the line separated by the insulator or dielectric have the property of capacitance. With alternating current in the line, the inductance causes a counter-emf to be produced along the line. This counter-emf opposes the applied voltage so that the voltage between the conductors at the receiving end is somewhat less than that across the terminals of the source. Also, with alternating voltage applied to the line, the capacitance has a shorting effect by permitting a small alternating current between the line conductors. Again a power loss exists, since the receiving device has less voltage applied to it and less current delivered to it than it would if it could be connected directly to the source terminals.

Since the resistance, conductance, capacitance and inductance

are not concentrated at any one point or group of points, but, instead, are distributed uniformly along the length of the line, they are known as **distributed properties**. The losses due to the distributed resistance and conductance of a given line depend, respectively, upon the current in and voltage between the conductors. On the whole, these two line properties remain fairly constant with changes of frequency, except for the increase in a-c resistance caused by skin effect as frequency rises.

On the other hand, the inductive and capacitive reactances vary considerably with frequency. At power line frequencies, the inductive reactance of the transmission line is so low, and the capacitive reactance so high that the effect of these distributed properties is of no importance compared with that of the conductor resistance and insulation conductance. As frequency increases, the inductive reactance becomes greater to produce a higher counter-emf, and there is a corresponding decrease in the reactance of the distributed capacitance to permit greater shorting of the current by the transmission line. Finally, at VHF and higher, the line resistance and conductance are of little importance compared with the effects of the inductive and capacitive reactances.

Figure 2A shows a section of the **twin-lead** type of transmission line which is employed between the television receiver and antenna. The two copper conductors are held at a constant distance apart and are insulated from each other by the flexible plastic covering. The distributed inductance and capacitance properties of this line are indicated schematically in Figure 2B. Thus, each conductor can be considered a long coil, each short section of which has a small inductance. A small capacitance exists between each point along one conductor and the corresponding point on the other conductor. This actual distribution cannot be illustrated easily pictorially or schematically, but the drawing of Figure 2B gives the general idea.

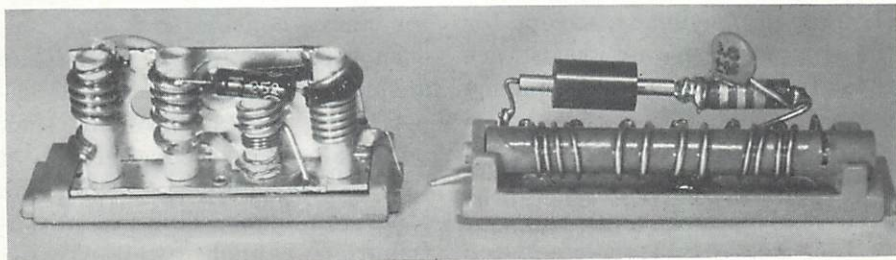
At the frequencies of the VHF and UHF television carriers, the carrier wavelengths range from a fraction of an inch to several feet. Therefore, with the antenna located on the roof of a house, the lead-in is considerably longer than a wavelength of the signal current it transmits to the receiver. It has been found that the distributed inductance and capacitance cause a transmission line to act like a resonant circuit if its length is exactly equal to one or more quarter wavelengths of the signal current. When this condition exists, the line is called a **RESONANT LINE**. Such a line does

not transfer energy efficiently from source to receiving device, therefore a NONRESONANT LINE is required for the television receiver lead-in.

However, the resonant properties of transmission lines are useful in UHF tuners. As mentioned, sections of lines are employed as tuned circuits. Usually, such tuned circuits consist of sections of line

forms the only path at this point to complete the circuit for the r-f current. Consequently, the current is very small at the open end, but the voltage is maximum.

As indicated, the transmission line has a length equal to one-quarter of the wavelength of the applied alternating voltage. As a result of these length relationships, a 90° phase difference exists



UHF tuning strips. The preselectors, crystal mixer, i-f output transformer, and harmonic selector are mounted on the strip at left. The harmonic generator, bias network, and the VHF mixer and oscillator tuning coils are shown on the strip at right.

DTI Photo

equal in electrical length to one-quarter wavelength or one-half wavelength (two-quarter wavelengths) of the UHF carrier wave to be received.

Figure 3A shows an a-c generator connected to a pair of parallel conductors which form a transmission line. This line has distributed inductance and capacitance as explained for Figure 2. In Figure 3A, the line is open (not connected) at the end opposite that to which the r-f voltage is applied. Because of this arrangement, the capacitance between the ends of the conductors

between the current at the generator end and the current at the open end, and also between the voltages at the two ends of the line. Therefore, at the generator end of the line of Figure 3A, the current is maximum and the voltage minimum.

As we know from Ohm's law for a-c circuits, a small voltage can produce a large current only when the circuit has a very low impedance. For the particular frequency at which the signal wavelength is four times the length of the transmission line, a small applied voltage produces a much

larger current in the line of Figure 3A than would be permitted by either an inductance or capacitance alone with values equal to those of the line. Also, as the frequency is increased or decreased, the same applied voltage produces less and less current.

This is the same result that is obtained when an a-c source is connected to the series LC circuit shown in Figure 3B. That is, as the source frequency is varied, the circuit current increases when the frequency approaches resonance. At the resonant frequency, the circuit presents minimum impedance to the source, and the circuit current is maximum. Thus, the open-end quarter-wave line section of Figure 3A presents the same impedance to a voltage source as that presented by a series resonant LC circuit.

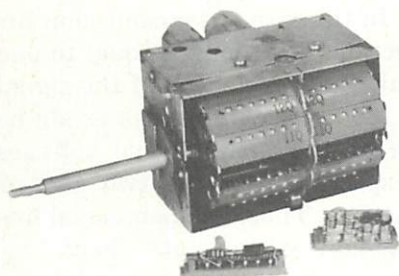
When a short is placed across the end of the line as shown in Figure 3C, the current and voltage conditions are exactly opposite those in the open end line. In the shorted quarter-wave line, the current is maximum at the shorted end, while the voltage is minimum at this point. Therefore, at the end connected to the source, the current is minimum and the voltage is maximum. Thus, so far as the voltage source is concerned, the line has high impedance because a large applied voltage can produce only a small current

at the input terminals of the line. The impedance decreases to permit more current as the frequency is made higher or lower than that at which the signal wavelength is four times the length of the line. Therefore, the shorted quarter-wave line of Figure 3C presents the same impedance to the source as that presented by the parallel resonant LC circuit of Figure 3D.

In the case of transmission line sections with length equal to one-half the wavelength of the signal, a 180° phase difference exists between the currents and voltages, respectively, at the two ends of the line. Thus, an open-ended line, one-half wavelength long, has maximum voltage and minimum current at the open end, like the line of Figure 3A. However, although of opposite direction compared with that at the open end, the voltage is maximum and the current minimum at the input end also. Therefore, the open-end half-wave line section presents maximum impedance to the source at the resonant frequency, like the parallel LC circuit of Figure 3D. The shorted half-wave line has minimum voltage and maximum current at both ends, and presents the source with minimum impedance at resonance like the series LC circuit of Figure 3B.

When the section of line has a length other than a quarter wave-

length, or multiple thereof, it presents reactance to the applied signal. The reactance is either inductive or capacitive depending upon the length of the line and whether it is open or shorted. Any transmission line has what is known as a CHARACTERISTIC IMPEDANCE due to the distributed properties of inductance, capacitance, and resistance. Maximum



The bottom view of the turret tuner showing tuner strips used for UHF reception.

Courtesy Standard Coil Products Co.

transfer of energy is obtained between signal source and line, or line and load, when the source or load impedance is equal to the characteristic impedance of the line. When the line length is one-eighth or an odd multiple of one-eighth wavelength, the reactance it presents is equal numerically to the characteristic impedance of the line.

For example, the one-eighth wavelength open line of Figure 4A presents a capacitive reactance equal to the characteristic

impedance of the line, while the one-eighth wave shorted section of Figure 4B presents inductive reactance equal to the line impedance. If the sections of Figures 4A and 4B are joined, they form a quarter wave shorted section like that of Figure 3D, and therefore, from the input, act like a parallel resonant circuit.

Furthermore, the open line section of Figure 4A can be replaced by a capacitor with reactance equal to the characteristic impedance of the line. If this capacitor is connected to the one-eighth wave shorted section, as shown in Figure 4C, the arrangement is equivalent to that of Figure 3C, and forms a parallel resonant circuit. This is the form commonly employed as the tuning circuits in the preselector and the tank circuit of the oscillator in UHF television tuners.

When the receiver tuned circuits consist of coils and capacitors as in Figure 3D, the resonant frequency is changed by varying either the inductance or capacitance or both. When the transmission line sections are used, the resonant frequency is changed by varying the electrical length of the line. This variation is accomplished either by sliding a shorting bar along the line as shown in Figure 4D, employing a variable capacitor as in Figure 4E, or a combination of both.

Local Oscillator

When employed as the local r-f source in a UHF tuner, an oscillator must provide reasonably constant output over a wide range of frequencies. This operation requires that there be minimum change in the feedback voltage ratio from plate to grid circuit as the tank is tuned over the range. In the case of oscillator circuits such as the Hartley which depend on inductive feedback, the coupling between the coils varies with frequency, causing the feedback ratio to vary over the tuning range.

This variation is minimized in the Colpitts oscillator, the basic circuit of which is shown in Figure 5. Here, the tank consists of L_1 , C_3 , and C_4 , and the grounded connection between the capacitors divides the tank r-f voltage between the grid and plate circuits of V_1 . Shunt fed through r-f choke L_2 , the triode plate is coupled through blocking capacitor C_2 to the upper end of the tank. Thus, the r-f voltage across C_4 is applied between the plate and grounded cathode of V_1 . In the grid circuit, C_1 and R_1 produce grid leak bias, and C_1 couples the grid to the lower end of the tank. Hence, the r-f voltage across C_3 is applied between the grid and cathode of the tube.

Because of the 180° phase difference between the voltages at

the upper and lower ends of the tank, when the upper end is maximum negative, the lower end applies a positive peak to the grid to produce a pulse of plate current. The resulting variation of plate voltage forms the feedback voltage applied across C_4 . The ratio of the feedback to the voltage across the entire tank is equal to the ratio of the equivalent capacitance of C_3 and C_4 in series to the capacitance of C_4 . Thus, capacitive coupling provides feedback from the plate section to the grid section of the tank in the Colpitts oscillator. The feedback ratio remains constant so long as the capacitance ratio is unchanged. If capacitance is employed for tuning, both capacitors must be varied to maintain the desired constant feedback ratio.

Alternative methods of tuning are switching in additional turns of L_1 , switching in entire coils or tank circuits, varying a capacitor connected across the entire tank, and varying both L_1 and a parallel capacitor.

Other advantages of the Colpitts type oscillator are that it contains fewer LC combinations which can generate spurious oscillations, and its untapped coil has one less connection to be made when coils are switched in and out for tuning purposes.

In the circuit of Figure 5, capacitor C_3 is in parallel with the

grid-cathode interelectrode capacitance of V_1 . Also, C_4 is in parallel with the plate-cathode interelectrode capacitance of V_1 . As the oscillator is designed to operate at higher and higher frequencies, the capacitances of C_3 and C_4 are decreased, and approach the values of the interelectrode capacitances. The final result is the complete elimination of C_3 and C_4 , leaving only the interelectrode capacitances, C_{pk} and C_{gk} , in series across the coil. This arrangement is illustrated in Figure 6.

The oscillator circuit of Figure 6, known as an Ultraudion, actually is a variation of the Colpitts type oscillator. Indicated here with dashed lines, C_{pk} performs the function of C_4 , and C_{gk} the function of C_3 of the circuit of Figure 5. Since the cathode of V_1 is grounded, the grounded connection between the tank capacitances in Figure 6 represents the cathode sides of C_{pk} and C_{gk} , respectively. Thus, the tube capacitances provide the required division of the r-f tank voltage. Although C_1 and C_2 are in series between L_1 and the grid and plate respectively, their capacitances are so large compared with C_{pk} and C_{gk} that they have almost no effect on the resonant frequency of the tank. For this reason, Figure 6 shows C_{pk} and C_{gk} in the position of C_4 and C_3 of Figure 5, instead

of to the right of C_1 and C_2 which would represent their physical location.

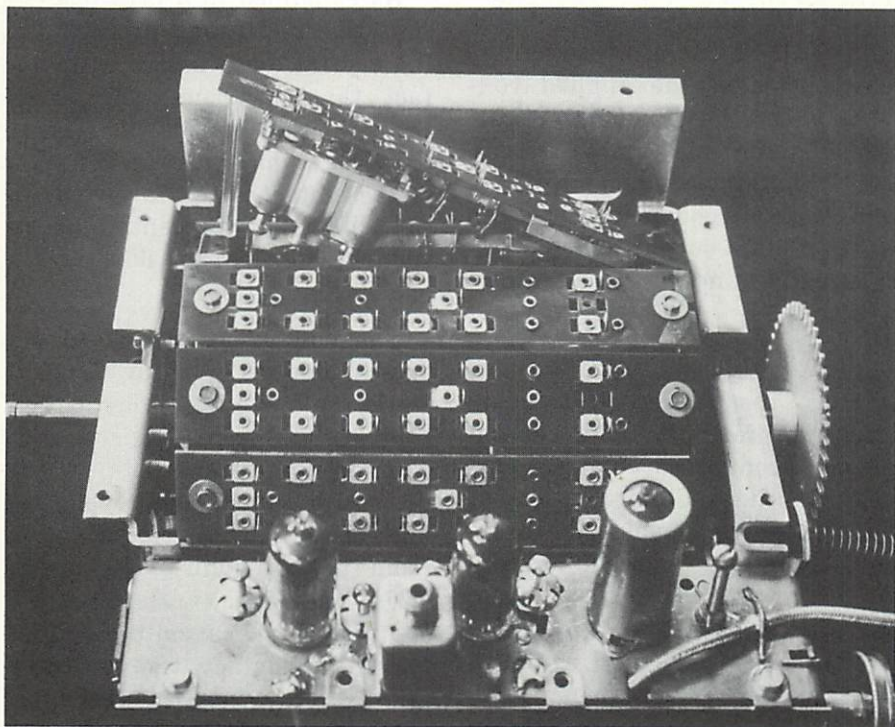
The Ultraudion oscillator of Figure 6 is the basic form of the h-f oscillators employed in television UHF tuners. To be described later, the actual circuits contain variations to increase stability and provide means of tuning. Blocking capacitor C_2 may be omitted, thus placing L_1 at the direct voltage of the V_1 plate. L_1 may be a coil, or the inductance of a transmission line section. In the latter case, the tank is shunted by the capacitance of the line. A variable capacitor may be connected across the tank for tuning purposes, and in addition, a trimmer added to provide for alignment.

To reduce the undesirable loading effect of the tube on the tank circuit, a number of tubes have been designed especially for use in UHF oscillator circuits. An example is the triode type 6AF4. This 7-pin miniature tube has a transconductance of 6600 micromhos, amplification factor of 15, grid to cathode capacitance of $2 \mu\mu\text{f}$, and plate to cathode capacitance of $0.45 \mu\mu\text{f}$. Its plate and grid connect to two base pins each. This arrangement reduces lead inductance since separate paths are thus provided for the r-f and direct current components.

Mixer

Referring to Figure 1, the mixer stage receives the UHF carriers from the preselector and the output of the r-f source, and heterodynes them to form intermediate frequency signals. To perform the heterodyning process,

result in a conductance component in the input circuit of the tube, and thus lower the Q of any tuned circuit connected or coupled to the grid of the tube. To minimize these undesirable actions in the mixer stage, a crystal diode rectifier is employed instead of an



Turret tuner with the UHF tuning strip partially in place. Note the UHF converter circuit is mounted on a single strip.

Courtesy Zenith Radio Corp.

the mixer circuit contains a rectifying device. In lower frequency receivers, the rectification is provided by a triode, pentode, or pentagrid electron tube. However, as mentioned, transit-time effects

electron tube. The operation of the diode mixer has been explained in a previous lesson.

Figure 7 illustrates the circuit of the mixer stage used in the UHF tuner. Reviewing the action

briefly, the r-f voltages coupled through T_1 and T_2 add to produce pulses of direct current in D_1 . Since the applied r-f voltages have different frequencies, the pulses of diode current vary in amplitude according to the instantaneous sum of the input voltages. The average value of the current pulses increases and decreases at the rate of the difference between the frequencies of the applied voltages. Thus, the diode circuit carries a pulsating direct current, which contains components at the difference frequencies between the oscillator output and the picture and sound carriers, respectively.

The load circuit L_1C_1 is tuned to accept these difference frequencies. Therefore, the diode current pulses produce circulating currents in the L_1C_1 circuit, at the difference frequencies. As a result, one r-f voltage appears across L_1 and C_1 which carries the amplitude modulation of the picture carrier, and another which carries the frequency modulation of the sound carrier. These modulated r-f voltages form the picture and sound i-f carriers, and are coupled from the tap on L_1 through L_2 and C_2 to the input of the i-f amplifier.

The structure of a typical point-contact type crystal diode is shown in Figure 8. The crystal consists of a slab of silicon or germanium,

and the rectifying contact point is the small surface at which the pointed metal wire touches the crystal. Both crystal and contact wire are enclosed in an insulating case through which leads connect the diode elements to the external circuit.

As explained in a previous lesson, the rectifying property of the crystal diode arises from the fact that electrons pass easily through the boundary between the crystal material and the point of the contact wire. However, this same boundary presents high resistance to electron flow in the opposite direction.

The equivalent circuit of the crystal diode is given in Figure 9. Here, the switch S_C , when closed, represents the low resistance to electron flow from crystal to contact wire, and when open, the high resistance to electron flow from the wire point to the crystal. This "variable resistance" is shunted by the capacitance C_C between the contact wire and crystal. R_s represents the resistance offered by the body of the crystal, called the "spreading" resistance. The inductance of the leads and the capacitance between them are represented by L_1 and C_1 , respectively.

Because the contact wire actually presses lightly against the surface of the crystal, the boundary between them is extremely

thin, on the order of one-millionth of a centimeter. Since the crystal is the cathode and the wire the anode of the diode, the very small distance between them makes the electron transit time very short, even compared with the UHF wavelengths. Consequently, the input conductance of the crystal diode is much less than that of an electron tube. This difference in transit time is the principal advantage of the crystal diode mixer over the circuits employing tubes.

In any diode, the interelectrode capacitance bypasses a portion of the applied signal, and this portion is lost so far as rectification is concerned. Represented as C_c in Figure 9, this capacitance can be made much smaller in a crystal diode than the plate to cathode capacitance in an electron tube diode. In the crystal unit, C_c decreases as the area of the contact point is decreased. The minimum area of this point is limited by the power which the diode is designed to handle in a given application. For UHF uses, the crystal and its holder and leads are physically small so that L_1 and C_1 resonate only at an extremely high frequency.

Compared with electron tube diodes, crystal mixers have the disadvantage of a greater conversion loss. When the diode is an electron tube, a grid leak resistor

and capacitor arrangement is employed to provide a bias such that diode conduction occurs only during the positive peaks of the local oscillator r-f voltage. Under such conditions, the conversion conductance is only slightly less than the average conductance over the oscillator cycle. Therefore, the i-f signal output is not a great deal lower than the r-f signal voltage applied to the mixer.

However, in the case of the crystal mixer, a bias greatly increases the noise generated by the crystal. Therefore, the crystal mixer is operated usually without a bias. The diode conducts during the entire positive alternations of the applied oscillator voltage, and the conversion conductance is very much less than the average conductance. The conversion loss is great, since these conditions cause the i-f output to be considerably less than the r-f signal input.

Preamplifier

To make up for the reduction of signal level caused by the crystal mixer stage in the UHF tuner, the mixer i-f output is amplified before being applied to the conventional i-f amplifier in the receiver. This preliminary amplification is performed by an amplifier represented by the last block in Figure 1. Since this amplifier operates in the intermediate fre-

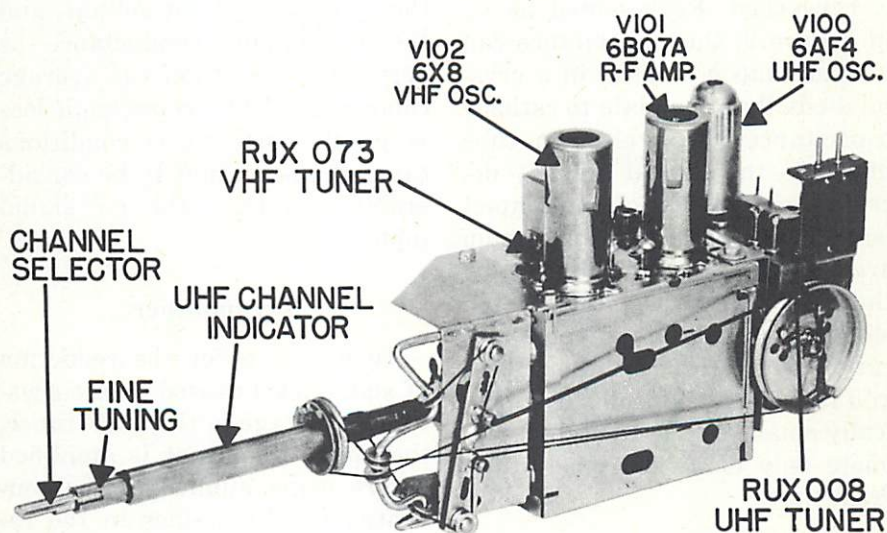
quency band, but is ahead of the stages which provide the main i-f amplification, it is referred to sometimes as the **pre-i-f amplifier**.

UHF Tuner System

The diagram of Figure 10 illustrates the connections of the pre-selector circuit, Ultraudion type h-f oscillator, crystal diode mixer, and pre-i-f amplifier to form a UHF tuner. The tuned circuits of the preselector and h-f oscillator consist of transmission line sections designated L_1 , L_2 , and L_3 in the Figure. In some tuners, these line sections are actually con-

structed in circular shape for compactness and ease of tuning adjustments. This design is indicated by the circular line symbols in Figure 10. The first two lines L_1 and L_2 are employed in the preselector, while L_3 is the oscillator tank. The ganged shorting bars slide along the lines to change their electrical length to provide for tuning over the UHF range.

From the antenna, the sound and picture r-f carrier signals are applied across the balanced input resistors R_1 and R_2 , and are coupled through C_1 , C_2 , and L_4 to the input end of line L_1 . Acting as a



In this tuner assembly, the UHF unit is mounted at the rear of the VHF tuner. Both units are operated by control knobs mounted on concentric shafts.

Courtesy General Electric

parallel resonant circuit, L_1 presents high impedance to the carriers and sidebands of the channel to which it is tuned, but provides a low impedance path to ground for currents at all other frequencies. The small variable inductor L_4 and capacitor C_4 permit alignment adjustments. The output of the L_1 tuned circuit appears across the two capacitors C_3 and C_4 from which it is coupled through C_5 and C_6 to the second section of the preselector, line L_2 . From this tuned circuit, the signal voltage is coupled by C_9 to the cathode of the crystal diode mixer, D_1 .

In both L_1 and L_2 , as the shorting bar is moved around in the counterclockwise direction, it shortens the electrical length of the used portion of the line. At the same time, the length of the line increases between the grounded end and the shorting bar. If this unused part of the line becomes resonant, oscillations take place in it, and rob energy from the circuit. This action is referred to as SUCK OUT, and results in a decrease in the level of the signal applied to the mixer. Damping resistors R_3 and R_4 load the unused part of the line to prevent these undesirable oscillations.

Triode V_1 and the transmission line tank circuit L_3 form an Ultraudion oscillator. The V_1 plate is shunt fed through r-f chokes

L_8 and L_9 and resistor R_6 from the B+ supply. One terminal of L_3 is coupled by blocking capacitor C_{11} to the plate of V_1 . The other terminal is coupled to the grid by the padding inductor L_6 and capacitor C_{10} . R_5 and C_{10} provide grid leak bias.

When the oscillator operates above approximately 760 mc, strong oscillations occur in the unused portion of L_3 unless the inner conductor is connected back on itself as shown. If not prevented in this way, the suck out of energy from the used portion reduces the oscillator output, and sometimes causes the desired oscillations to stop entirely.

In the V_1 cathode circuit, coil L_7 serves as the output load coil. The r-f voltage at the cathode is coupled through C_{12} to the crystal mixer cathode. Since this is the same point to which the preselector output is connected, the oscillator output is also coupled through C_9 to the tuned circuits of the preselector. If any of the oscillator energy passes through the preselector to the antenna, it is radiated by the antenna, and may cause interference in nearby television receivers. To prevent this undesirable action, the preselector circuits provide low impedance paths to ground for currents at the frequency of the oscillator. These paths are obtained by connecting the shorted ends of

L_1 and L_2 through damping resistors R_3 and R_4 to ground.

In the mixer circuit, diode D_1 is connected in shunt with its load, the primary of T_1 . With its anode grounded, D_1 conducts to short the circuit during the negative portions of the input voltages, but is nonconductive during the positive portions. Applied in series with low pass filter L_{10} to the T_1 primary, the positive voltage pulses produce current containing components at the oscillator, r-f, and beat frequencies. In this diagram, the V_2 stage is the pre-i-f amplifier. Tuned by the input capacitance of V_2 to resonance at the beat frequency, the T_1 secondary applies the i-f output of the mixer to the grid of V_2 . In the V_2 plate circuit, the amplified i-f signal is coupled by T_2 to the main i-f amplifier in the receiver.

UHF TUNER CIRCUITS

Up to this point, we have described the various requirements and certain design methods which apply to UHF tuning systems in general. Although Figure 10 shows a certain construction for the tuned transmission line sections, the main purpose of this schematic is to illustrate how the various stages are coupled to form a complete tuner. For the above general explanation, the diagram was not intended to represent any particular make or model. Actually, it is

the circuit of a tuner developed by P. R. Mallory & Co., and employed with variations by a number of television receiver manufacturers. However, in addition to this tuner, units of other makes contain transmission line sections as resonant circuits, some of which have the circular construction indicated by L_1 , L_2 , and L_3 in Figure 10.

In the various commercial receivers, several distinct methods have been employed to accomplish the functions of the basic system illustrated in Figures 1 and 10. The method used most frequently is indicated by the block diagram of Figure 11. Here, the selected UHF picture and sound carriers are applied by the preselector to the mixer, and a UHF oscillator generates a h-f r-f voltage which is applied to the mixer also.

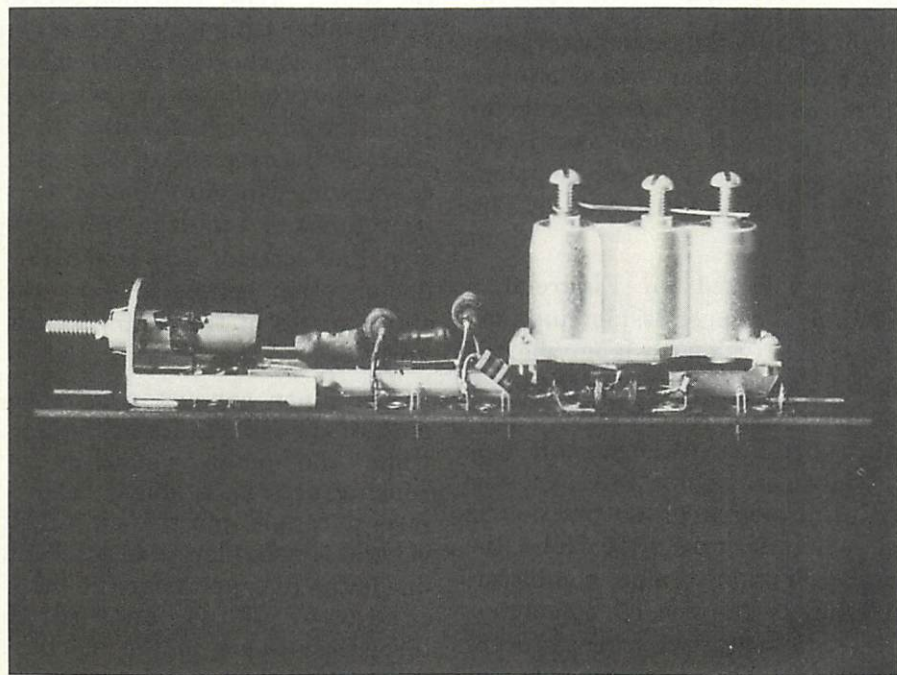
So far, the action is basic to all tuners. However, the arrangement which identifies this method is the fact that the r-f amplifier and converter stages of the VHF tuner form a two-stage pre-i-f amplifier for the i-f output of the UHF mixer. When the receiver is switched to a channel in the UHF band, the VHF tuning circuits are disconnected and replaced by circuits tuned to accept the frequencies employed in the receiver i-f amplifier. Usually, these frequencies are in the 40 mc range. The UHF mixer stage provides an i-f output in this range. Thus, in the

method illustrated by Figure 11, the receiver VHF tuner contributes the additional amplification needed, as explained for the amplifier block of Figure 1.

Figure 12 shows a typical UHF tuner circuit of the type which employs the method of Figure 11. The preselector consists of the transmission line sections L_1 and L_2 and the associated inductors and capacitors such as L_4 , C_4 , L_5 , C_5 , etc. Having very small values, these inductors and capacitors provide the L and C adjustments necessary to align the various tuned circuits. As indicated by

their shape in the drawing, L_1 , L_2 , and L_3 are constructed in the circular manner described for Figure 10. Triode V_1 with its tuned circuit L_3 is an Ultraudion oscillator, the output of which is coupled from the grid through C_{10} to the cathode of the mixer diode D_1 . The preselector output is coupled through C_9 to this same point.

Produced across L_{15} and C_{13} , the i-f signals are coupled through the shielded line and L_{16} to a terminal on selector switch S_1 in the VHF tuner circuit. S_1 is shown in the position for receiving in the UHF band. In this position, the



Used in a turret type tuner, a single mounting board holds all the components of this UHF strip.

Courtesy Zenith Radio Corp.

sliders to L_{17} ground the VHF tuning circuits. A slider connects L_{16} to C_{15} , thus coupling the UHF mixer i-f output to the grid of V_2 , the VHF cascode type r-f amplifier.

Although not included in Figure 12, other switches provide tuned circuits resonant in the i-f band for coupling the output of V_2 to the input of the VHF converter tube. As explained, both of these stages amplify the i-f signal before it is applied to the main i-f amplifier in the video channel.

Another common physical construction employed for the tuned transmission line sections has the form of a rectangular metal strip enclosed in a metal box or case. The strip is the inner conductor while the enclosure or box is the outer conductor. The development of this form is illustrated in Figure 13.

As explained for Figure 3, a section of transmission line one-quarter wavelength long, shorted at the end, has the properties of a parallel resonant circuit. A parallel-wire line section of this type is shown in Figure 13A. Another transmission line construction is shown in Figure 13B. Here, the hollow cylinder, one conductor, surrounds the second conductor. Not shown, insulating spacers maintain the inner conductor at the center of the outer conductor. Like the parallel-wire line, the

coaxial line acts as a tuned circuit when a quarter-wave section is shorted at one end as shown. To provide a method of tuning, the line can be shortened, and a variable capacitor connected across the open terminals as shown in Figure 13C.

The mechanical adaptation of the tuned coaxial line section is shown in Figure 13D. The part which corresponds to the inner conductor of the coaxial line is the metal strip, U-shaped in cross section, and mounted in the tuner housing. The metal housing itself forms a metal enclosure around the center strip, and thus serves as the outer conductor. The inner conductor is shorted by the metal housing at the lower end where it joins the housing. Mounted on a shaft at the free end of the inner conductor, capacitor plates may be rotated to tune the transmission line section. The inner conductor strip serves also as the stator plates of the tuning capacitor.

The inner conductor provides most of the inductance of the line, while the outer conductor or housing acts as a shield. Therefore, to couple into this circuit, it is necessary to place the small coil inside the line, and near the inner conductor. Thus, extending through cut-outs in the housing, the coil provides link coupling as indicated by the lumped circuit schematic in Figure 13E.

Figure 14 shows a typical UHF tuner circuit, employed in many receivers, which uses the method of Figure 11 and the coaxial tuning circuit construction of Figure 13D. In this assembly, the tuner housing contains a central partition which separates the unit into two coaxial line sections. In the Figure, the left section contains the U-shaped metal strip as the inner conductor L_3 , and forms a single stage preselector. A flat metal strip, L_6 is the inner conductor of the coaxial section which forms the UHF oscillator tank. The tuning capacitors, C_5 and C_6 , are indicated schematically. C_7 and C_8 are trimmer capacitors which are designed for screw-driver adjustment. Each of these trimmers consists of a metal tab attached to the inner surface of the outer conductor. Turning the screw in bends the tab closer to the inner conductor to increase the capacitance. The oscillator tube V_1 is contained within the tuner housing. Common types in this application are the 6T4 and 6AF4.

The preselector line is a quarter-wave section, shorted at one end to form a parallel LC circuit which may be tuned over the UHF carrier band. Somewhat shorter in physical length, the oscillator line is a half-wave open line which may be tuned over the required range of the UHF oscillator. As mentioned for Figure 3, a half-

wave open line is equivalent to a quarter-wave shorted line in that both have the properties of a parallel resonant circuit. With the grid of V_1 connected to the inner conductor and the plate coupled through C_{10} to the outer conductor of the resonant line, the oscillator circuit is the Ultraudion type.

From the UHF antenna terminals, the incoming signal passes through the high-pass filter consisting of C_1 , C_2 , L_1 , C_3 , and C_4 . This filter has a cut-off frequency of approximately 325 mc. Since this frequency lies midway between the upper limit of VHF channel 13 and the lower limit of UHF channel 14, the filter passes UHF signals but attenuates VHF signals. From the filter output, the signal is coupled into the preselector by means of a two-turn loop L_2 placed close to the inner conductor L_3 , of the tuned line. The signal is coupled from the preselector to mixer diode D_1 by means of coupling inductor L_4 . Actually, L_4 is a length of wire run close and parallel to the inner conductor L_3 .

In series with L_4 and D_1 , the coupling loop L_5 couples energy from the oscillator tuned line to the mixer circuit. The i-f signal is developed across the parallel components L_{11} and C_{14} which comprise the mixer load. A low impedance output from the UHF tuner is obtained by connecting



Placed on the cabinet of a VHF receiver, this UHF converter employs tuned transmission line sections for receiving channels 14 through 83.

Courtesy P. R. Mallory & Co., Inc.

the output cable to the tap on L_{11} as shown. From this point, the i-f signal is carried by the cable to the input of the r-f amplifier stage in the VHF tuner. As explained previously for this system, when the receiver channel selector switch is set to a UHF channel, the VHF tuner r-f and converter stages operate as amplifiers to increase the level of the i-f output of the UHF mixer.

In the grid circuit of V_1 , Figure 14, capacitor C_9 permits adjustment of oscillator frequency dur-

ing factory alignment. The oscillator must cover the proper frequency range to provide proper tracking of the UHF circuits. Slight calibration shifts can be corrected by adjusting oscillator trimmer C_8 until the received signal is strongest when the receiver station selector switch is set to a station which employs a carrier near the low end of the UHF band.

In the V_1 plate circuit, C_{10} forms a low reactance path for r-f plate current to the outer con-

ductor of the oscillator tank circuit. Direct current passes through r-f choke L_7 to B+. A low-pass filter is formed by C_{11} , L_7 , and **feed-through capacitor** C_{12} to minimize the r-f component carried by the low voltage supply. Similar isolation is provided by the cathode and heater circuit chokes L_8 , L_9 , and L_{10} , and feed-through capacitor C_{13} .

A variation of the method of Figure 11 is illustrated by the block diagram of Figure 15. Here again, the incoming signal voltage and a h-f voltage from the local oscillator are applied to the mixer which produces picture and sound i-f carriers in the 40 mc range. The r-f amplifier and converter in the VHF tuner serve as a two-stage preamplifier for the i-f signals. In this and previous references to the i-f range, the term "40 mc" is used loosely. The actual picture and sound i-f value depend upon the particular receiver model. Common values are 41.25 mc for the sound i-f and 45.75 mc for the picture i-f.

The difference in this system is indicated by the two blocks at the lower center of the Figure. In this case, the h-f oscillator operates at one-half or one-third the frequency required to produce the desired beat frequencies when mixed with the incoming signal. The oscillator output is doubled or tripled, as required, by the

harmonic generator. The **harmonic selector** is a tuned LC circuit which selects the proper harmonic and applies it to the mixer. When the receiver is tuned from station to station, both the h-f oscillator and the harmonic selector must be tuned along with the preselector. An advantage of operating the h-f oscillator at a lower frequency than that required by the mixer is greater oscillator stability. A disadvantage is that the voltage provided to the mixer has lower amplitude, since the harmonic components are weaker than the fundamental generated by the oscillator circuit.

A UHF tuner employing the harmonic generator method is shown in Figure 16. Here, all of the tuner components are contained within a large enclosure, including the metal case which forms the outer conductors of the coaxial tuned lines. Shown at the lower left, this case contains two partitions to form three tuned lines. U-shaped metal strips, L_2 , L_5 , and L_8 , serve as the inner conductors of the respective lines. The lines indicated by L_2 and L_5 , and tuned by ganged capacitors C_1 and C_3 , are the preselector tuned circuits. The somewhat shorter line L_8 , tuned by C_5 , is the harmonic selector circuit.

Tubes V_1 and V_2 are connected as a push-pull, tuned plate-tuned grid oscillator. The tuned grid cir-

cuit consists of coil L_{11} which is self resonant at the lower end of the tuning range, while the tuned plate circuit consists of L_{10} and the split-stator tuning capacitor C_{13} and C_{14} . Plate tank inductor L_{10} is a flat piece of sheet metal shaped in the form of a horseshoe. Variable inductor L_{12} is connected in parallel with L_{10} to permit adjustment of the plate circuit inductance. C_9 and C_{10} provide feedback from the plate circuit to the grids to maintain oscillation while C_{12} permits adjustment of oscillator tracking near the high end of the tuning range.

The oscillator output is coupled from L_{10} to L_9 which, with crys-

tal diode D_2 , forms the harmonic generator circuit. The produced harmonic frequencies are fed by the extension of L_9 into the harmonic selector tank, L_8 . C_5 tunes this tank to the second harmonic (in this case) of the oscillator frequency. From a tap on L_8 , this selected harmonic is coupled through r-f choke L_7 to the mixer diode D_1 . The incoming UHF signal is coupled by L_1 into the first preselector stage, and by L_3 and L_4 into the second tuned line of the preselector. In operation longer loop L_3 is effective primarily at the low frequency end of the UHF band, while smaller loop L_4 is effective primarily at the high frequency end of the band. From the tap on L_5 , the signal is coupled through r-f choke L_6 to the mixer circuit.

The i-f signal is produced across coil L_{14} which is slug-tuned to permit i-f alignment. From this point, the signal is link coupled by L_{15} to a short length of coaxial cable through which the signal is fed to the input of the VHF tuner. Switch S_1 is shown in the UHF receiving position. The VHF tuner is disconnected from the VHF antenna terminals, and these terminals grounded. In the other position of this switch, the UHF tuner is disconnected, while the VHF antenna terminals are connected to the VHF tuner.

In the UHF tuner of Figure 16, the oscillator is tunable over a



A UHF Converter. By connecting the antenna lead-in to one pair of terminals and the receiver lead-in to another pair, switching from VHF to UHF is accomplished by simply rotating the left hand knob.

Courtesy General Electric Co.

range from 258.5 mc to 465.5 mc. Therefore, the second harmonic produced by the D_2 circuit varies over the range from 517 mc to 931 mc, the range required to produce the 41.25 mc sound i-f and 45.75 video i-f over the band. In the D_1 mixer circuit, the $C_7L_{13}R_3$ network provides a test point for checking tuner operation during production testing.

In both the tuner methods described so far, the mixer circuit produces an output in the frequency band of the picture and sound intermediate frequencies employed in the receiver. That is, like the VHF tuner, these UHF tuners convert the carrier frequencies from those received by the antenna to those to which the main i-f amplifier circuits are designed to pass. This system is known as **single conversion**.

In a second general system, called the **double conversion** method, the tuner converts the incoming carriers to the carrier frequencies employed in an unused VHF channel. The UHF tuner output is then applied to the VHF tuner, set to this channel, which then converts the carriers to the required picture and sound intermediate frequencies. Thus, frequency conversion occurs twice, with the VHF tuner operating the same as though the signals had been received in the VHF band.

As employed in television receivers, the double conversion system can be represented by the block diagram of Figure 15. Two methods have been used. In one, the UHF tuner contains all of the circuits indicated by the lower row of blocks in the Figure, plus the mixer stage. In the other method, the UHF tuner contains these same stages with the exception of the h-f oscillator. In this case, the oscillator in the VHF tuner serves as the source of r-f voltage which forms the input to the harmonic generator in the UHF tuner.

In both methods, the UHF mixer provides a choice of carriers in two VHF channels. Usually, channels 5 and 6 are used. That is, the output is in either one or the other of these channels, whichever is not being used by a VHF station in a given area.

UHF CONVERTERS

Besides the UHF tuning methods employed in the television receivers, there are a number of separate units, called UHF converters, on the market. The purpose of these units is to permit UHF operation by receivers designed for VHF reception only. When one or more UHF stations begin operating in an area originally served by VHF stations only, the receiver owner can adapt his equipment to receive

the UHF signals by installing a UHF antenna system and adding a UHF converter. Usually, the converter can be placed on top of the receiver cabinet for separate manual control.

The UHF converters employ the same tuned circuit constructions, oscillator types, and crystal mixer circuits described previously for the receiver tuners. In addition, the converters include a self-contained preamplifier, and a power supply as shown in Figure 17.

As an example, one model includes the circuit of Figure 10, plus its own power supply. The converters employ the double conversion system. That is, the mixer stage produces carrier signals at the frequencies of the r-f carriers in either of two VHF channels, such as 5 and 6. The preamplifier stage increases the level of these carriers and applies them to the input of the VHF tuner in the receiver.

Up to this point, we have described the circuits and explained the action in the various sections of the television receiver. However, any complete receiving unit includes a more or less elaborate

antenna system in addition to the receiver proper. The antenna system is a very important part of the complete unit. The best receiver that can be designed is of little use unless there is applied to its input an undistorted signal of sufficient strength. The antenna has the job of providing this signal.

The complete antenna system consists of two parts. First, the antenna proper which contains one or more conductors or elements of proper length and relative position to produce an adequate signal voltage at its output terminals. Second, a lead-in or transmission line, connected between the antenna terminals and receiver input terminals. The transmission line should deliver a maximum of the antenna output without distortion to the receiver tuner.

Because of the great importance of these two antenna system components, and the large variety of receiving conditions which require different antenna system designs, the following two lessons are devoted to a description of the antennas and transmission lines employed for receiving VHF and UHF television signals.



STUDENT NOTES

STUDENT NOTES

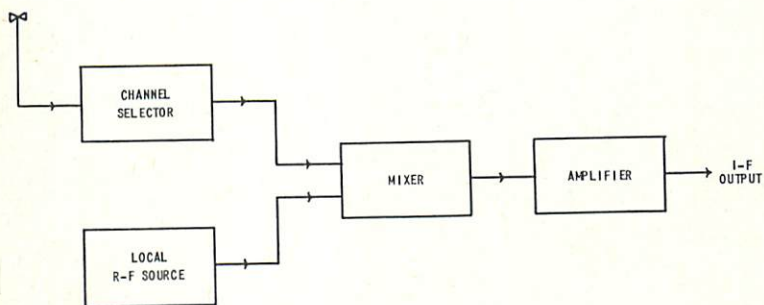


FIGURE 1

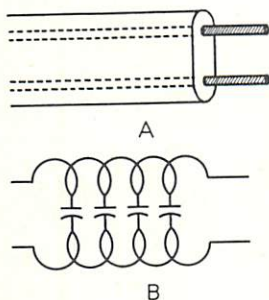


FIGURE 2

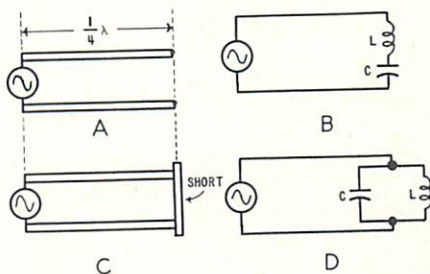


FIGURE 3

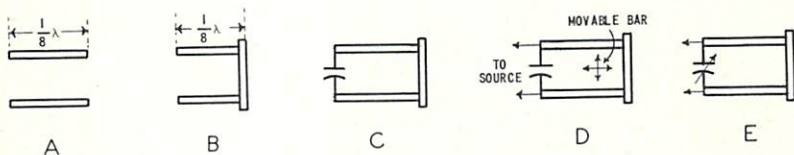


FIGURE 4

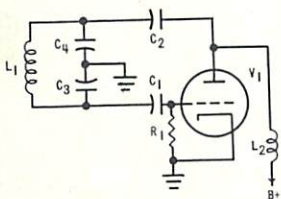


FIGURE 5

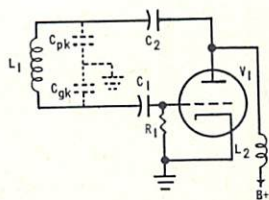


FIGURE 6

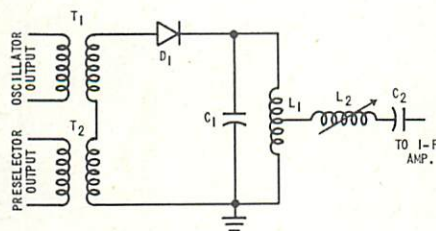


FIGURE 7

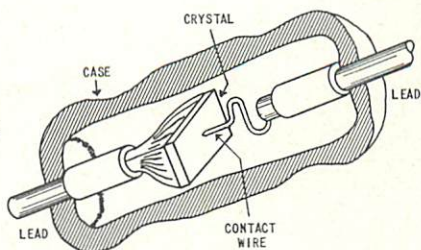


FIGURE 8

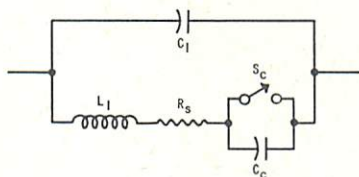


FIGURE 9

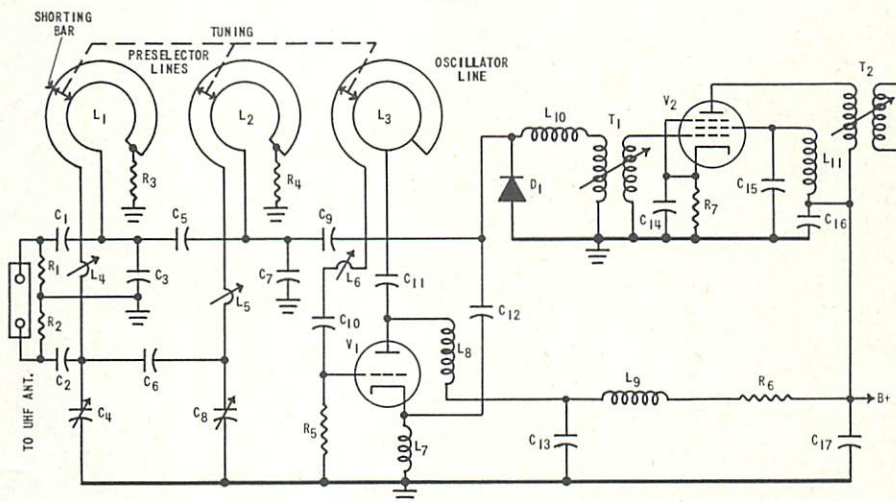


FIGURE 10

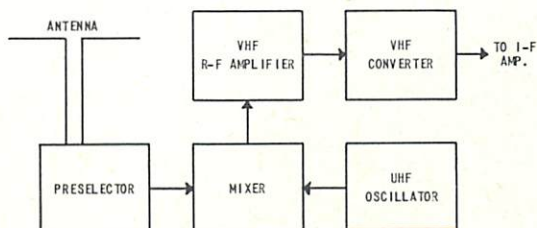


FIGURE 11

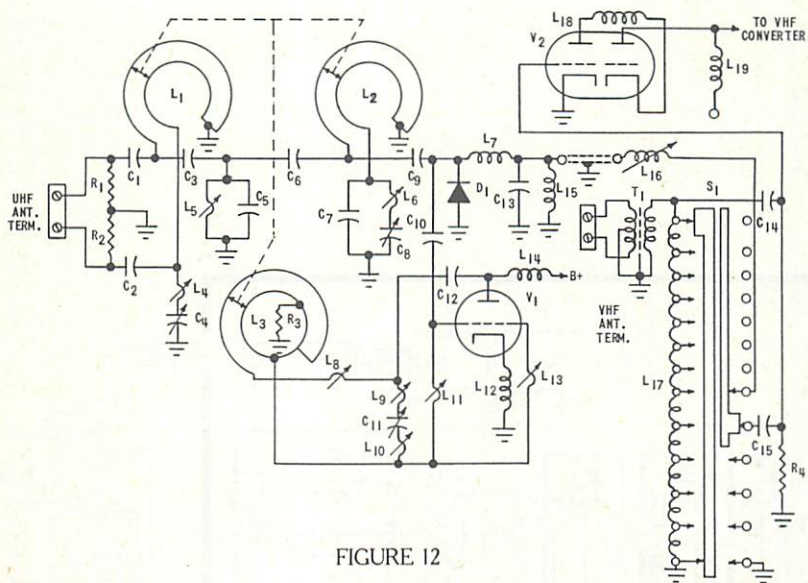


FIGURE 12

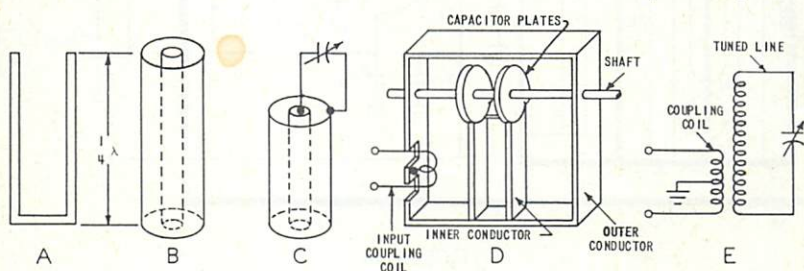


FIGURE 13

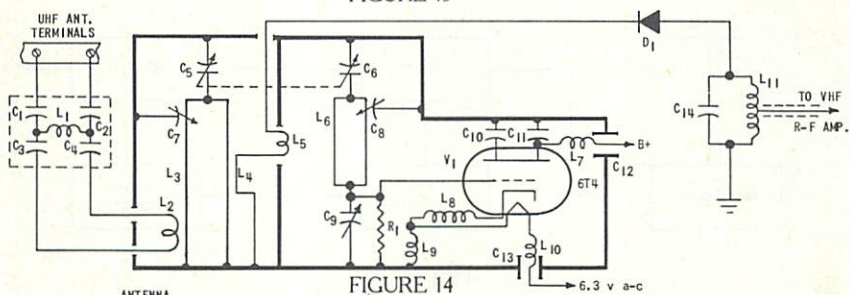


FIGURE 14

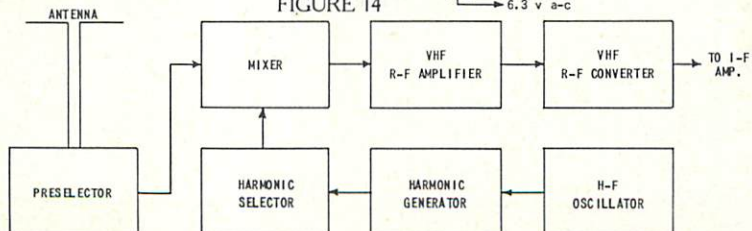


FIGURE 15

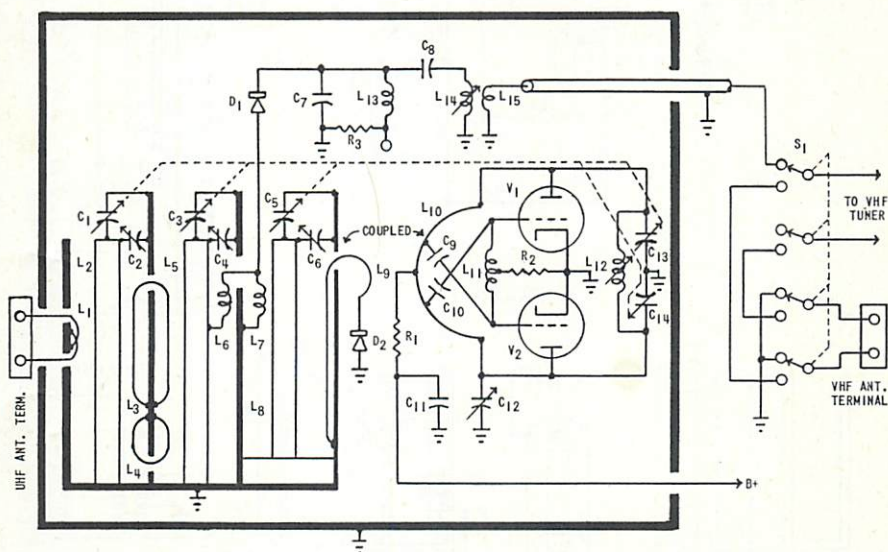


FIGURE 16

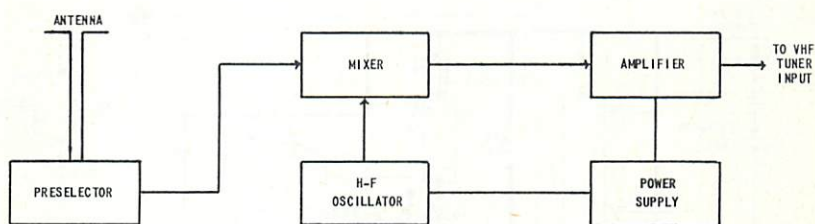


FIGURE 17

FROM OUR *Director's* NOTEBOOK

THE MAN WHO WINS

The man who wins is an average man,
Not built on any peculiar plan.
Not blest with any peculiar luck,
Just steady and earnest and full of pluck.

When asked a question he does not "guess"—
He knows, and answers, "no" or "yes".
When set a task that the rest can't do.
He buckles down 'til he's put it through.

Three things he's learned: That the man who tries
Finds favor in his employer's eyes;
That it pays to know more than one thing well;
That it doesn't pay all he knows to tell.

So he works and waits, 'til one fine day
There's a better job with bigger pay.
And the men who shirked whenever they could
Are bossed by the man whose work was good.

For the man who wins is the man who works,
Who neither labor nor trouble shirks,
Who uses his hands, his head, his eyes;
The man who wins is the man who tries.

—Charles R. Barrett

Yours for success,

W. C. R. Vrey
DIRECTOR